PN JUNCTION DIODES AND RECTIFIER CIRCUITS

AE

Naval Air Technical Training Comma

CNATT-J121 PAT

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

test, but a learning situation. There will always be an instructor available to answer any questions you might have concerning the information being presented.

You will proceed from page to page, as in a conventional book. On each page, you will find one or more numbered sections. These sections are called "frames." You will go from frame to frame, using a piece of paper to cover upcoming frames. There is no advantage in peeking at new information. To be effective, you must follow the sequence. You must respond to each frame before you uncover the correct response. AFTER writing or selecting your response, be sure to check the left side of the next frame to see if your response was correct.

If your response was wrong, strike it out, reread the frame, and select another response. If your response was correct, continue with the next frame.

At the end of this program, there is a self-test to check what you have gained from the lesson.

Turn to page ii and read the objectives.

SUGGESTED READING TIME 90 MINUTES

The student will:

1. Select, from a list of statements, the one which describes the forming of a PN junction.

2. Select, from a list of statements, the one which defines junction resistance.

3. Select, from a list of statements, the one which defines forward bias.

4. Select, from a list of statements, the one which defines reverse bias.

5. Select, from a list of statements, the one which describes current flow in the external circuit.

6. Select, from a list of statements, the operating limitations of a PN junction diode.

7. Complete a PN junction diode circuit by drawing in the symbol for the PN junction diode to indicate forward bias.

8. Select, from a list of statements, the purpose of a rectifier.

9. Compute the average voltage output of a half-wave rectifier for a given maximum secondary voltage.

10. Write the formula for computing the average value of output voltage for a full-wave rectifier.

11. Compute the average voltage output of a four-diode full-wave bridge rectifier for a given maximum secondary voltage.

features of semiconductor diodes compared to vacuum tubes.

diode. Semiconductor diodes are used for rectifiers and detectors.

It is convenient to speak of PN junctions as being "joined" together. Actually, a PN junction is formed during a manufacturing process in which the P-type and the N-type material form a single crystal. A PN junction diode would not work if the materials were mechanically joined.

When P-type and N-type semiconductor materials are joined together, a ____ ______________ is formed.

PN junction

2. Select, from the statements below, the one which describes the forming of a PN junction. Circle the letter preced[ing] your choice.

   a. When P-type and N-type materials a[re] placed together in a semiconductor diode.

   b. When P-type and N-type materials are joined together in a semiconductor diode.

	ACCEPTOR atom into germanium. The trivalent acceptor atom entering into covalent bond with surrounding germani atoms accepts an electron from a neighboring atom, creating a hole. Thi action causes the acceptor atom to become a negative ion. When an acceptor atom was injected into the germanium, an electron was removed from a neighboring atom, creating a ______________ in the P-type material.
hole	4. The P-type material has an overall neutral charge. For every negative ion that is created, there is also a positive hole to compensate for it.

o Holes

The negative ions in the P-type material are neutralized by the same number of positively charged holes; therefore, the P-type material has an overall ______________ electrical charge.

---

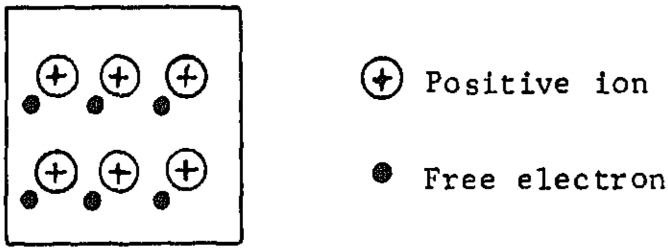
neutral or zero

5. The N-type material of a semiconductor diode is created by injecting a DONOR atom into germanium. The pentavalent donor atom enters into covalent bond with neighboring germanium atoms, leaving an electron that is free to move about. This action causes the donor atom to become a positive ion.

lectrons

6. The N-type material has an overall neutral electrical charge. For every positive ion created, there is an electron to compensate for it.

Note the drawing of N-type material.



For each positive ion present, a free electron neutralizes its electrical charge; therefore, the N-type material has an overall

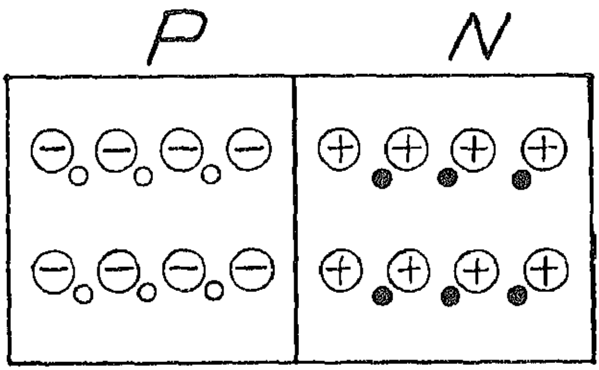
______________ electrical charge.

	are electrons. The majority carriers in P-type material are holes, and the minority carriers are ______________.
electrons	The majority carriers in N-type material are electrons, and the minority carriers are ______________
holes	The majority carriers in P-type material are ______________, and th majority carriers in N-type materia are ______________.

s

are joined together, the holes and electrons nearest the junction will combine. When these majority carriers combine, they will leave uncompensated ions. (Remember, the ions are held in covalent bonds and are unable to move about within the crystalline structure.)

Note the drawing below.



The N-type material was initially neutral, and the loss of some of its electrons will leave it with a

________________ (negative/positive)

charge.

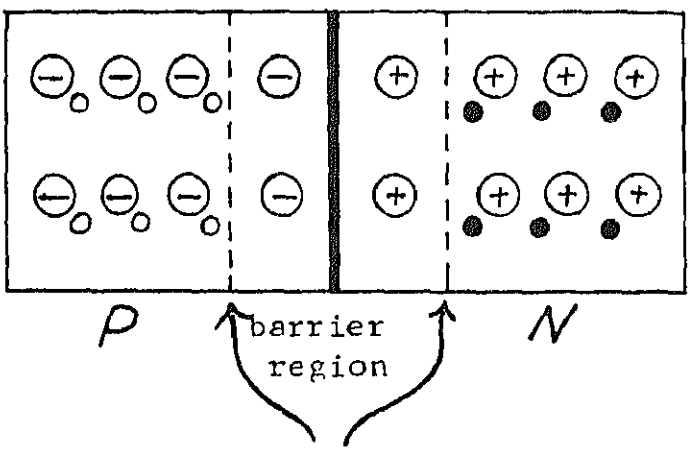
	N-type material, the P-type material will have a ______________ (negative/ positive) charge.
negative	When additional electrons from the N-type material attempt to approach the junction, they will be repelled by the ______________ charge of the P-type material.
negative	If holes from the P-type material attempt to approach the junction, they will be repelled by the ______________ charge of the N-type material.

will have an absence of ____________

and ____________ ____________.

holes free electrons	9. The absence of holes and free elect near the junction leaves uncompensa ions. Since the uncompensated ions the junction repel further attempts majority carriers to combine, and th is an absence or depletion of major carriers, this area is known as the depletion or barrier region.

Note the drawing below.



and the N-type material with a positiv
charge. This difference in potential
may be represented by a small battery
and is referred to as the barrier
potential.

The depletion or barrier region is the
area near the junction which has an
absence of ____________ and
____________ ____________.

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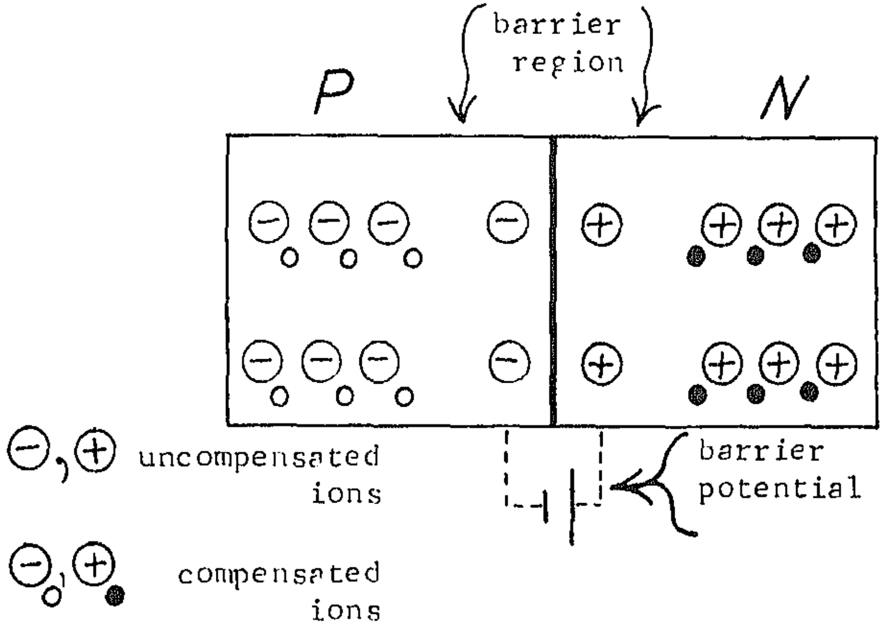
holes free electrons	The difference in potential, caused b the loss of holes and free electrons, is referred to as the ____________ ____________.

depletion region and the barrier potential as a small battery.



In PN junction diodes, the loss of holes in the P-type material will give the P-type material a ______________ (positive/negative) charge.

	_______________ (positive/negative) charge.
positive	The loss of holes and free electrons in the area near the PN junction causes a difference in potential, referred to as the _______________ _______________.
barrier potential	11. The combining of holes and electrons near the junction left uncompensated ions and caused the barrier potential which offers an opposition to the further combining of majority carriers. This opposition, near the junction, is commonly referred to as junction resistance.

	but will be repelled by the positively charged ______________ in the N-type material.
...s	The formation of a PN junction in semiconductor material will occur when the majority carriers nearest the junction combine and a ______________ potential is established which will prevent further ______________.
...rier ...bination	When a barrier potential is established in semiconductor material by combining the majority carriers in the P-type and the N-type material, a(n) ____ ______________ is formed.

	the ________ ________.
junction resistance or barrier potential	Once the PN junction is formed, the junction resistance (barrier potential is the opposition offered to the further combining of ________ ________.
majority carriers	The opposition offered to the further combining of majority carriers, once the PN junction is formed, is the ________ ________.

potential	(barrier potential). Circle the letter preceding your choice. a. The opposition offered to the furth combining of minority carriers, once the PN junction is formed. b. The opposition offered to the furth combining of majority carriers, once the PN junction is formed. c. The opposition offered to the furth combining of uncompensated ions, once the PN junction is formed.
b. is correct.	14. When a battery is connect PN junction, bias the ju voltage whi CONTINUE ON PAGI

	the ______________ .
junction resistance or barrier potential	Once the PN junction is formed, the junction resistance (barrier potential) is the opposition offered to the further combining of ______________ ______________.
majority carriers	The opposition offered to the further combining of majority carriers, once the PN junction is formed, is the ______________ ______________.

once the PN junction is formed.

b. The opposition offered to the furthe

combining of majority carriers,

once the PN junction is formed.

c. The opposition offered to the furthe

combining of uncompensated ions,

once the PN junction is formed.

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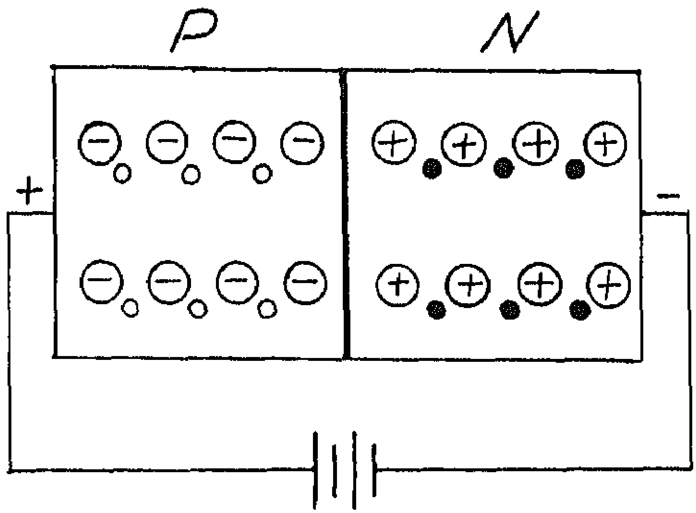
is correct.

14. When a battery is connected across the PN junction, the battery potential will bias the junction. (Bias is a d.c. voltage which sets the operating level.)

CONTINUE ON PAGE 16.

(low resistance).

Forward bias is applied to a PN junct
by connecting the positive battery
terminal to the P-type material and
the negative terminal to the N-type
material. Note the drawing below.

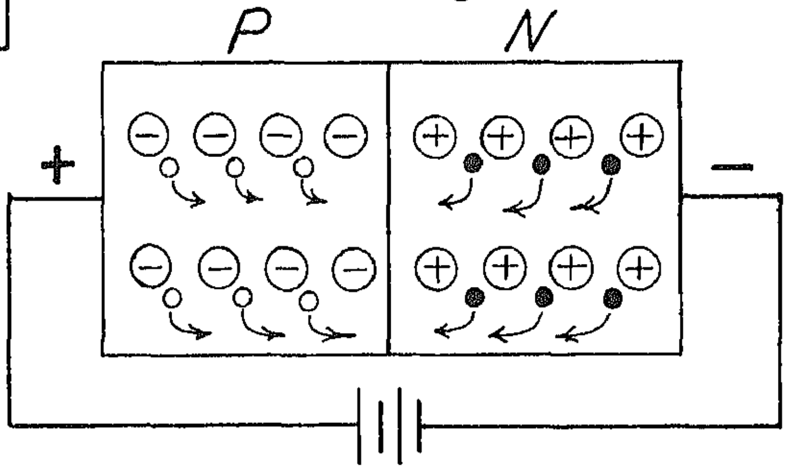


said to be biased in the ______________

(forward/reverse) direction.

ard

15. Note the drawing below.



The positive potential on the P-type material will repel holes toward the junction. The negative potential on the N-type material will repel electrons toward the junction. Forward bias will reduce the barrier potential and allow the majority carriers to cross the junction, therefore aiding conduction.

	(negative/positive) battery terminal and the N-type material is connected to the ____________ (negative/positive) battery terminal.
positive negative	The application of forward bias to a PN junction diode will aid conduction by ____________ (aiding/opposing) the barrier potential.
opposing	A PN junction diode will be biased in the forward direction when the negative battery terminal is connected to the ____-type material and the positive battery terminal is connected to the ____-type material.

		barrier potential.
oppose		Forward bias will ____________ (increase/decrease) barrier potential.
decrease	16.	Select, from the list of statements, the definition of forward bias. Circle the letter preceding your choice.

a. Opposes conduction by opposing the barrier potential.

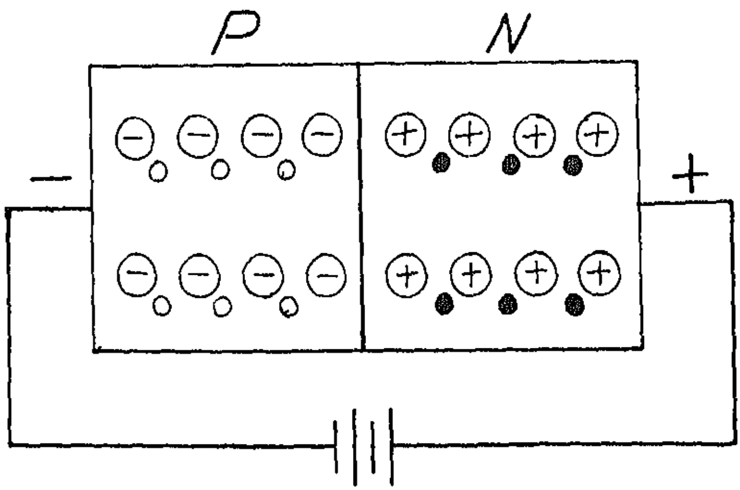
b. Opposes conduction by aiding the barrier potential.

c. Aids conduction by opposing the barrier potential.

d. Aids conduction by aiding the barrier potential.

conduction through the junction, and the junction is said to be biased in the reverse direction (high resistance).

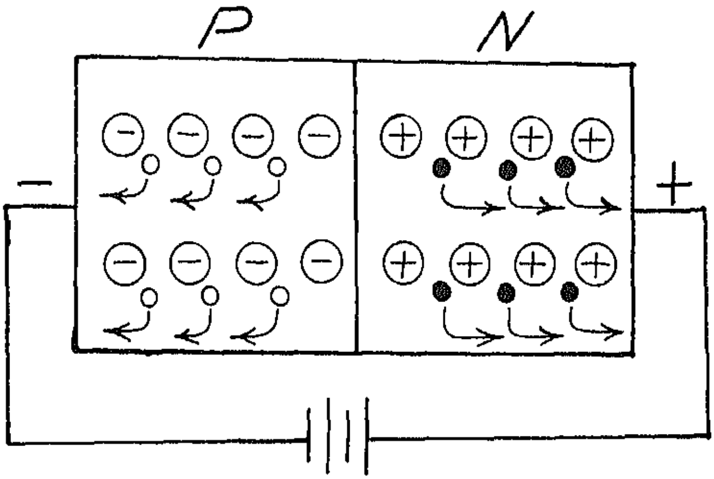
Reverse bias is applied to a PN junction by connecting the positive battery terminal to the N-type material and the negative terminal to the P-type material. Note the drawing below.



said to be biased in the ______________ (forward/reverse) direction.

se

18. Note the drawing below.



The negative potential on the P-type material will attract holes away from the junction, and the positive potential on the N-type material will attract electrons away from the junction. Reverse bias will increase the barrier potential and oppose conduction of majority carriers across the junction.

	(negative/positive) battery terminal and the N-type material is connected to the ____________ (negative/ positive) battery terminal.
negative positive	The application of reverse bias to a PN junction diode will oppose conducti by ____________ (aiding/opposing) th barrier potential.
aiding	A PN junction diode will be biased in the reverse direction when the negativ battery terminal is connected to the ___-type material and the positive battery terminal is connected to the ___-type material.

	carriers away from the junction and _____________ (aid/oppose) the barrier potential.
d	Reverse bias will _____________ (increase/decrease) barrier potential.
ncrease	19. Select, from the list of statements, th definition of reverse bias. Circle the letter preceding your choice.

a. Opposes conduction by opposing the barrier potential.

b. Opposes conduction by aiding the barrier potential.

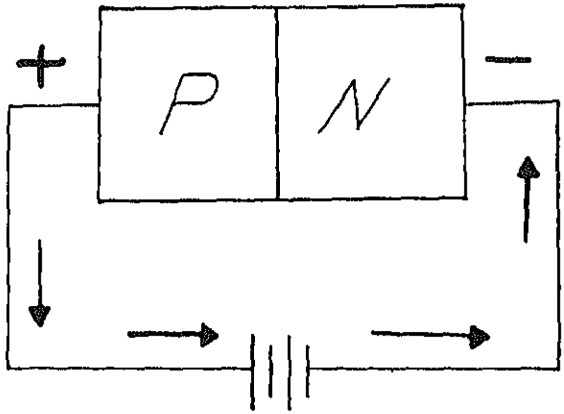
c. Aids conduction by opposing the barrier potential.

d. Aids conduction by aiding the barrier potential.

from the negative battery terminal

to the positive battery terminal.

Note the drawing below.



With forward bias applied to the d

current will flow from ____________

to ____________.

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negative positive	Current will flow, in the external circuit, with ____________ (forw reverse) bias applied to the diode

potential, preventing conduction, and will not allow current to flow in the external circuit.

Current will not flow, in the external circuit, with ______________ (forward/reverse) bias applied to the diode.

erse

The diode will conduct with ______________ (forward/reverse) bias applied, allowing current to flow in the external circuit, and will not conduct with ______________ (forward/reverse) bias applied.

preceding your choice.

a. In the external circuit, with forw
bias applied to a diode, current
flows from positive to negative.

b. In the external circuit, with reve
bias applied to a diode, current
flows from positive to negative.

c. In the external circuit, with reve
bias applied to a diode, current
flows from negative to positive.

d. In the external circuit, with
forward bias applied to a diode,
current flows from negative to
positive.

types of semiconductor materials. When forward bias is applied to a diode, conduction is due to the majority carriers being repelled toward the junction. When reverse bias is applied to a diode, conduction is opposed owing to the majority carriers being attracted away from the junction.

Remembering that the minority carriers in the P-type material are electrons, the minority carriers in the N-type material must be ______________.

conduction of minority carriers and

in the opposite direction of majorit

carrier current flow. Increasing th

reverse-bias voltage will increase t

minority current flow.

The amount of reverse-bias voltage t

causes excessive minority current fl

is called the breakdown voltage of a

diode.

The increase in reverse bias that ca

excessive minority current flow is

called the ______________ __________

of a diode.

called the ______________ ______________ of a diode.

n

25. Breakdown voltage is one of three limitations to the application of diodes. Each diode has its breakdown voltage listed by the manufacturer.

Another limitation is current. Current flow in the forward (low resistance) direction or reverse (high resistance) direction will cause heat in the diode. As current increases, the heat will also increase and eventually destroy the diode.

When current flows in a diode, ______________ is generated.

current	Two limitations in the application diodes are _____________ voltage a _____________.
breakdown current	26. A major limitation in the applicati of a diode is its temperature sensitivity. If, during the operat of a diode, the external or interna temperature is allowed to increase, internal resistance of the diode wi decrease. As the internal resistan decreases, the current through the diode increases and permanent damag results. As the temperature of a diode incre the internal resistance _____________

rease	A major limitation in the operation of a diode is its ______________ sensitivity.
perature	27. Select, from the list below, the operating limitations of a diode. Circle the letter(s) preceding your choice(s). a. Breakdown voltage b. Crystal defects c. Junction resistance d. Temperature e. Ions f. Current

and the vertical line, , represents the N-type material or cathode. Electron flow, in a semiconductor diode, is from the N-side to the P-side.

The direction of electron flow, relative to the symbol, , is always

__________ (with/against) the arrow.

---

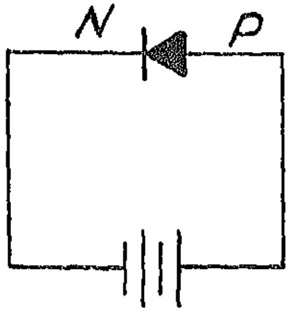
against

In the drawing below, the P-side and the N-side are labeled, and the direction of current flow is shown.

direction of current flow

Normal current flow through a diode is

__________ (with/against) the arrow.

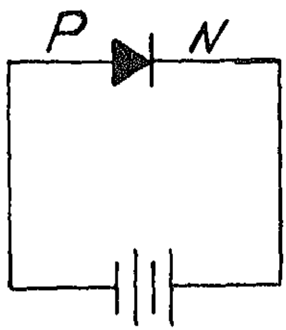


The circuit above is biased in the

_______________ direction.

ward

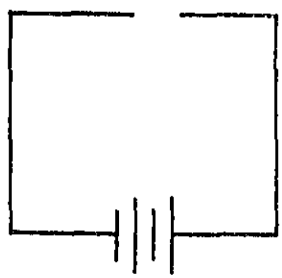
30. The circuit below represents a reverse-biased semiconductor diode.

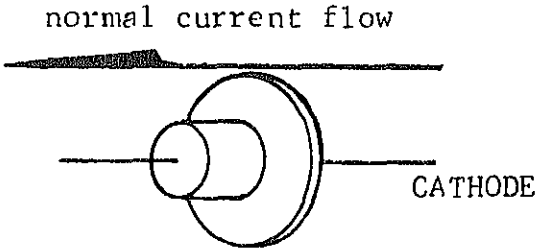


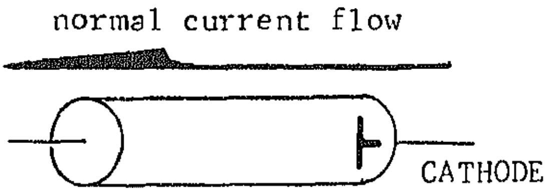
The circuit above is biased in the

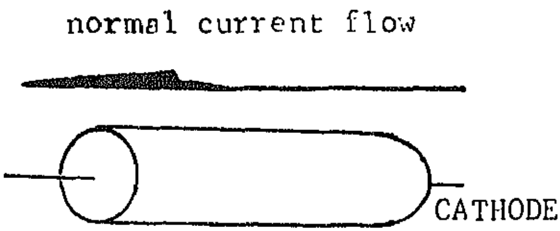
_______________ direction.

	represents the ______________ (anode/ cathode).
anode cathode	32. Draw a semiconductor diode symbol in the circuit below to indicate forward bias.









The cathode of most semiconductor diodes is usually identified by its shape or a mark, as shown in the illustrations above.

NO RESPONSE REQUIRED.

istics of low forward resistance and high reverse resistance. These two properties of PN junction diodes will allow them to be used as rectifiers.

A rectifier is a device that converts an a.c. input voltage into a pulsating d.c. output voltage.

The properties of a PN junction diode that allow it to be used as a rectifie are its ____________ (high/low) reverse resistance and its ____________ (high/low) forward resistance.

direction only.

An a.c. signal voltage applied to a rectifier will be converted to a pulsating d.c. voltage, because current only flows in one ____________ through a rectifier.

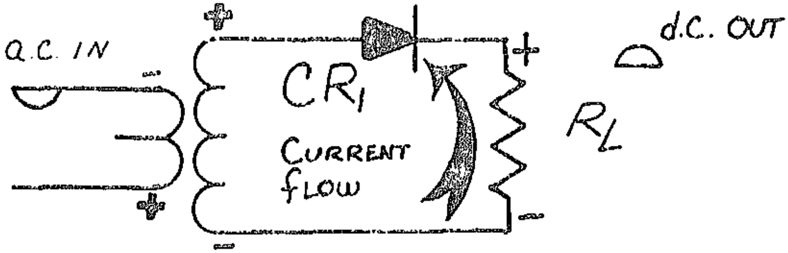
---

n

A rectifier will convert ____________ (a.c./d.c.) to pulsating ____________ (a.c./d.c.).

The conversion of an a.c. input signal voltage to a pulsating d.c. output voltage is accomplished by using a(n) ____________.

	a. Converts a pulsating d.c. input voltage to an a.c. output voltage. b. Converts an a.c. input voltage to pulsating d.c. output voltage. c. Converts an a.c. output voltage to a pulsating d.c. input voltage. d. Converts a pulsating d.c. output voltage to an a.c. input voltage.
b. is correct.	37. Keep in mind that there is a phase inversion across the windings of a transformer. The polarities of the first half-cycle are not circled, but the polarities of the second half-cycl are circled. NO RESPONSE REQUIRED.



The diode will allow current to flow when the top of the transformer secondary is positive (forward bias).

Majority-carrier current will flow through the load resistor (R_L) when the diode is biased in a ______________ (reverse/forward) direction.

---

39. Since the purpose of a rectifier is to convert an a.c. voltage to a pulsating d.c. voltage and current only flows through the load when the diode is forward-biased, the output will be pulsating d.c.

	During the second half-cycle, current will not flow through R_L, because the diode is ______________-biased.
reverse	40. An input of one cycle results in an output of one d.c. pulse. The output ripple frequency of a half-wave rectifi is equal to the input frequency. For an a.c. input signal of four cycle to a half-wave rectifier, the output would be ______________ d.c. pulses.
four	41. The average value of output voltage of a half-wave rectifier is equal to .318 times E_{max} of the secondary. ($E_{avg} = E_{max}$ times .318.)

The output ripple frequency of a half-wave rectifier is equal to the

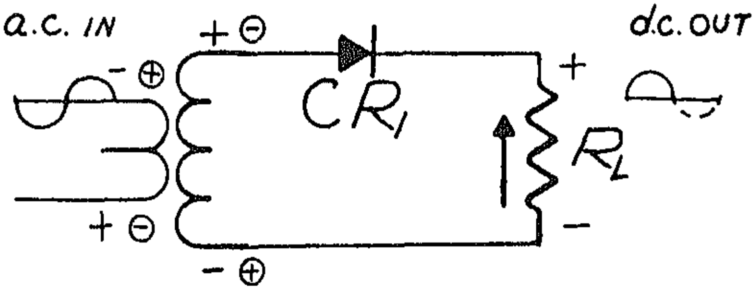
_______________ frequency.

The formula for computing the average value of output voltage of a half-wave rectifier is ________________________.

.318

42. Compute, for the circuit below, the average output voltage.

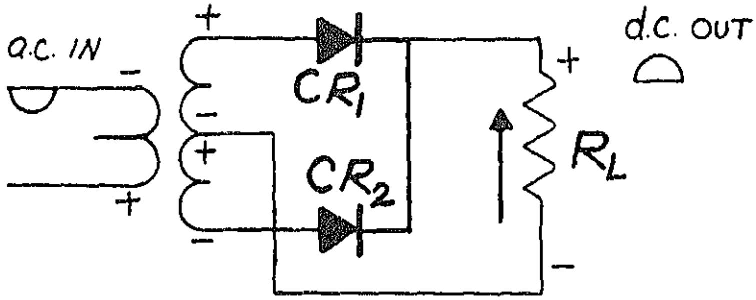
E_{max} of the secondary is 110 volts a.c.



E_{avg} = _______________ volts d.c.

tapped, the maximum voltage for each pa
of the rectifier circuit will be exactl
half of the secondary voltage.

Shown below is a two-diode full-wave rectifier circuit.



With a negative-going signal applied t the primary, CR_1 will conduct, because forward bias is applied. Current flow will be from the transformer center ta up t[illegible] [illegible]gh R_L, through CR_1, to the top of the transformer.

With a positive-going signal applied to the primary, CR_2 will conduct, because it has forward bias applied. Current flow will be from the transformer center tap up through R_L, through CR_2, to the bottom of the transformer. Current will not flow through CR_1 this time, because reverse bias is applied to it.

CR_1 will conduct when the top of the secondary is ______________ (positive/negative).

---

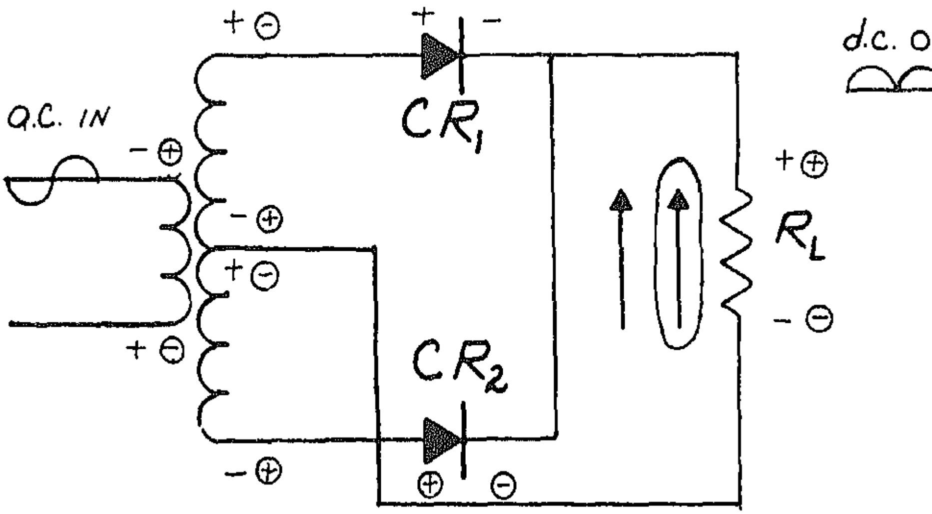
ive	CR_2 will conduct when the bottom of the secondary is ______________ (positive/negative).

(forward/reverse) biased.

forward

14 The full-wave rectifier will allow current flow through the load resisto (R_L) during the application of a posit or negative-going signal voltage.

Study the circuit below.



An input signal of one cycle results an output of two d.c. pulses. The output ripple frequency of a full-wav rectifier is equal to twice the input frequency.

t

45. The average value of output voltage of a full-wave rectifier is equal to .636 times E_{max} of the secondary. ($E_{avg} = E_{max} \times .636$). Remember, the transformer secondary of the full-wave rectifier is center-tapped. Therefore, the voltage applied to the conducting diode will be half of the secondary voltage.

An operating rectifier with a secondery voltage of 110 volts a.c. will have an average output pulse voltage of 34.98 volts d.c. (E_{max} will be half of the secondary voltage.)

substituting:

secondary voltage = 110 volts a.c.

E_{max} for the circuit conducting will be 55 volts a.c.

$E_{avg} = 55 \times .636$

therefore,

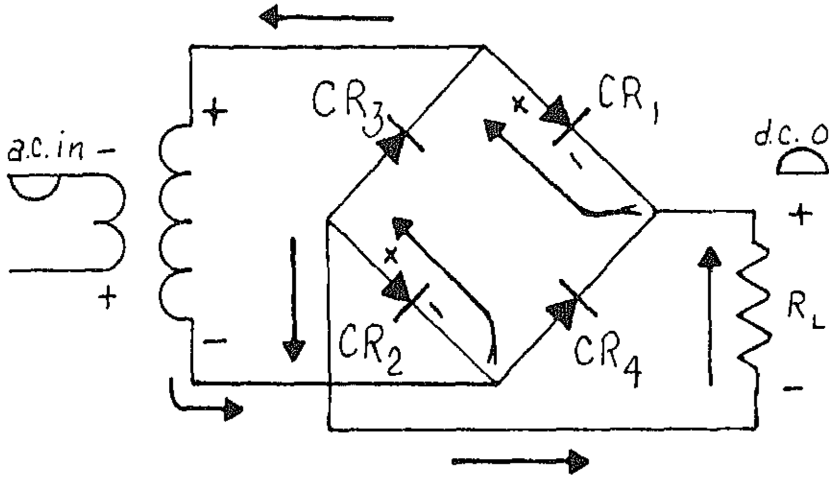
$E_{avg} = 34.98$ volts d.c.

An operating rectifier with a secondary voltage of 220 volts a.c. would provide an input voltage to one-half of the rectifier circuit of 110 volts a.c., and the resultant average output voltage would be ______________ volts d.c.

636

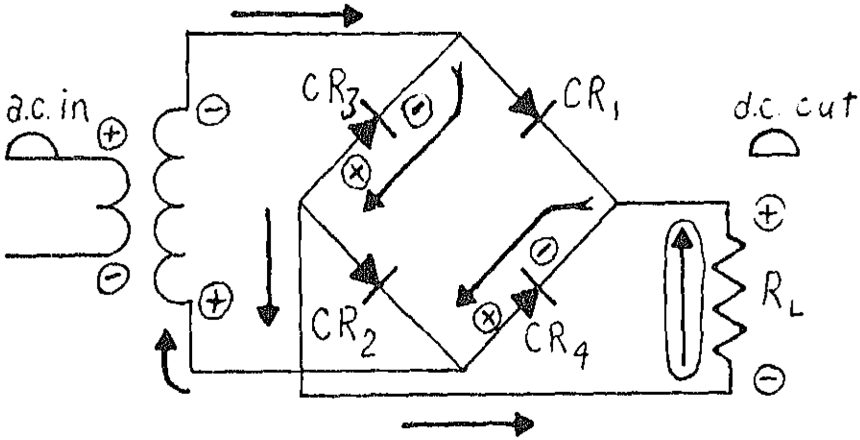
47. The full-wave bridge rectifier uses four PN junction diodes, and the transformer secondary is not center-tapped. The resultant average voltage outputs will be higher, because all of the secondary voltage is applied to the rectifier.

The advantage of using the four-diode full-wave bridge rectifier over the two-diode full-wave rectifier is the ______________ (higher/lower) average voltage output.



With a negative-going input signal t
the primary of the full-wave bridge
rectifier circuit, CR_3 and CR_4 will
not conduct, because they are revers
biased. CR_1 and CR_2 will conduct,
because they are ______________-bias

conduct. Note the current flow in the circuit below.



The output pulses of the full-wave bridge rectifier are identical with the output pulses of the rectifier using only two diodes. The output ripple frequency of a full-wave rectifier is equal to twice the input frequency.

The advantage of using the four-diode full-wave bridge rectifier over the two-diode full-wave rectifier is the average voltage output is _____________.

$E_{avg} = E_{max} \times .636$

A secondary voltage of 110 volts a.c

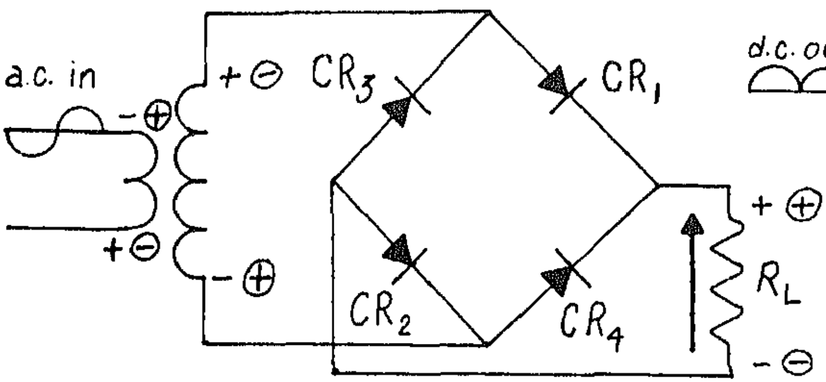
in a full-wave bridge rectifier circ

would result in an average output of

_______________ volts d.c

69.96 | 51. Compute, for the circuit below, the average output voltage.

E_{max} of the secondary = 220 volts a.



E_{avg} = _______________ volts d.c.

the diode. The peak reverse voltage (PRV) is the maximum reverse-bias voltage which may be applied to a diode and should be three times the value of the signal source voltage, owing to the capacitance of the circuitry.

The maximum reverse-bias voltage which may be applied to a diode is called the ______________________________ rating.

---

erse (PRV)

The peak reverse voltage (PRV) which may be applied to a diode is the maximum amount of _____________ (forward/ reverse) bias.

peak reverse voltage (PRV)	53. The major factor to consider when selecting diodes for use in rectifier circuits is the ________________ ____ __ ____________ ______.
peak reverse voltage (PRV)	54. There are several desirable features of semiconductor diodes over vacuum tubes. Because of the extremely small size and the light weight of the semiconductor diode, a considerable saving in the size and the weight of equipment is achieved. Two desirable features of a semi-conductor diode over a vacuum tube are the ____________ ____________ and the ____________.

diode, the internal resistance is very low. Compared to a vacuum tube, there is less power loss because of heat.

Three desirable features of semiconductor diodes compared to vacuum tubes are the small size, the light weight, and the low ____________ ____________.

56. The fourth desirable feature of a semiconductor diode is the long life. Because of the semiconductor diode's solid construction, life expectancy is very long.

Four desirable features of semiconductor diodes compared to vacuum tubes are the light weight, the small size, the low internal resistance, and the

____________ ____________.

	the letter(s) preceding your choice(s) a. light weight b. High internal resistance c. Long life d. Low internal resistance e. Large size f. Short life g. Small size h. Heavyweight
a., c., d., and g. are correct.	58. The major applications of PN junction diodes are signal detectors and power supply rectifiers. In this program, only rectifiers have been studied. Signal detectors will be covered in another lesson. A self-test begins on page 55. NO RESPONSE REQUIRED.

describes the forming of a PN junction. Circle the letter preceding your choice. (Frame 1)

a. When the P-type and the N-type material are placed together in a semiconductor diode.

b. When the P-type and the N-type material are joined together in a semiconductor diode.

2. Select, from the list of statements, the definition of junction resistance (barrier potential). Circle the letter preceding your choice. (Frame 3)

a. The opposition offered to the further combining of majority carriers, once the PN junction is formed.

b. The opposition offered to the further combining of minority carriers, once the PN junction is formed.

c. The opposition offered to the further combining of uncompensated ions, once the PN junction is formed.

3. Select, from the list of statements, the definition of forward bias. Circle the letter preceding your choice. (Frame 14)

a. Opposes conduction by opposing the barrier potential.

b. Opposes conduction by aiding the barrier potential.

c. Aids conduction by aiding the barrier potential.

d. Aids conduction by opposing the barrier potential.

b. Aids conduction by opposing the barrier potential.

c. Opposes conduction by aiding the barrier potential.

d. Opposes conduction by opposing the barrier potentia

5. Select, from the list of statements, the one that describes current flow in the external circuit. Circle the letter preceding your choice. (Frame 20)

   a. With forward bias applied to a diode, current flows from positive to negative in the external circuit.

   b. With forward bias applied to a diode, current flows from negative to positive in the external circuit.

   c. With reverse bias applied to a diode, current flows from positive to negative in the external circuit.

   d. With reverse bias applied to a diode, current flows from negative to positive in the external circuit.

6. Select, from the list below, the operating limitations of a diode. Circle the letter(s) preceding your choice(s). (Frame 24)

   a. Breakdown voltage

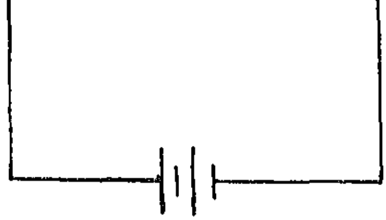
   b. Crystal defects

   c. Temperature

   d. Current

   e. Junction resistance

   f. Bias



8. Select, from the list below, the purpose of a rectifier. Circle the letter preceding your choice. (Frame 34)

   a. Converts a pulsating d.c. output voltage to an a.c. input voltage.

   b. Converts a pulsating d.c. input voltage to an a.c. output voltage.

   c. Converts an a.c. output voltage to a pulsating d.c. input voltage.

   d. Converts an a.c. input voltage to a pulsating d.c. output voltage.

9. Compute the average voltage output of a half-wave rectifier for a maximum secondary voltage of 110 volts a.c. (Frame 38)

   E_{avg} = ____________________

10. Write, on the line provided, the formula for computing the average value of output voltage for a full-wave rectifier. (Frame 43)

    ____

E_{avg} = ____________________

12. Complete the statement: The major factor to consider when selecting diodes for use in rectifier circuits is the ______________________________________ ratin
(Frame 52)

13. Select, from the list below, the desirable feature(s) of semiconductor diodes compared to vacuum tubes. Circle the letter(s) preceding your choice(s).
(Frame 54)

a. High internal resistance

b. Low internal resistance

c. Large size

d. Short life

e. Long life

f. light weight

g. Small size

h. Heavyweight

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